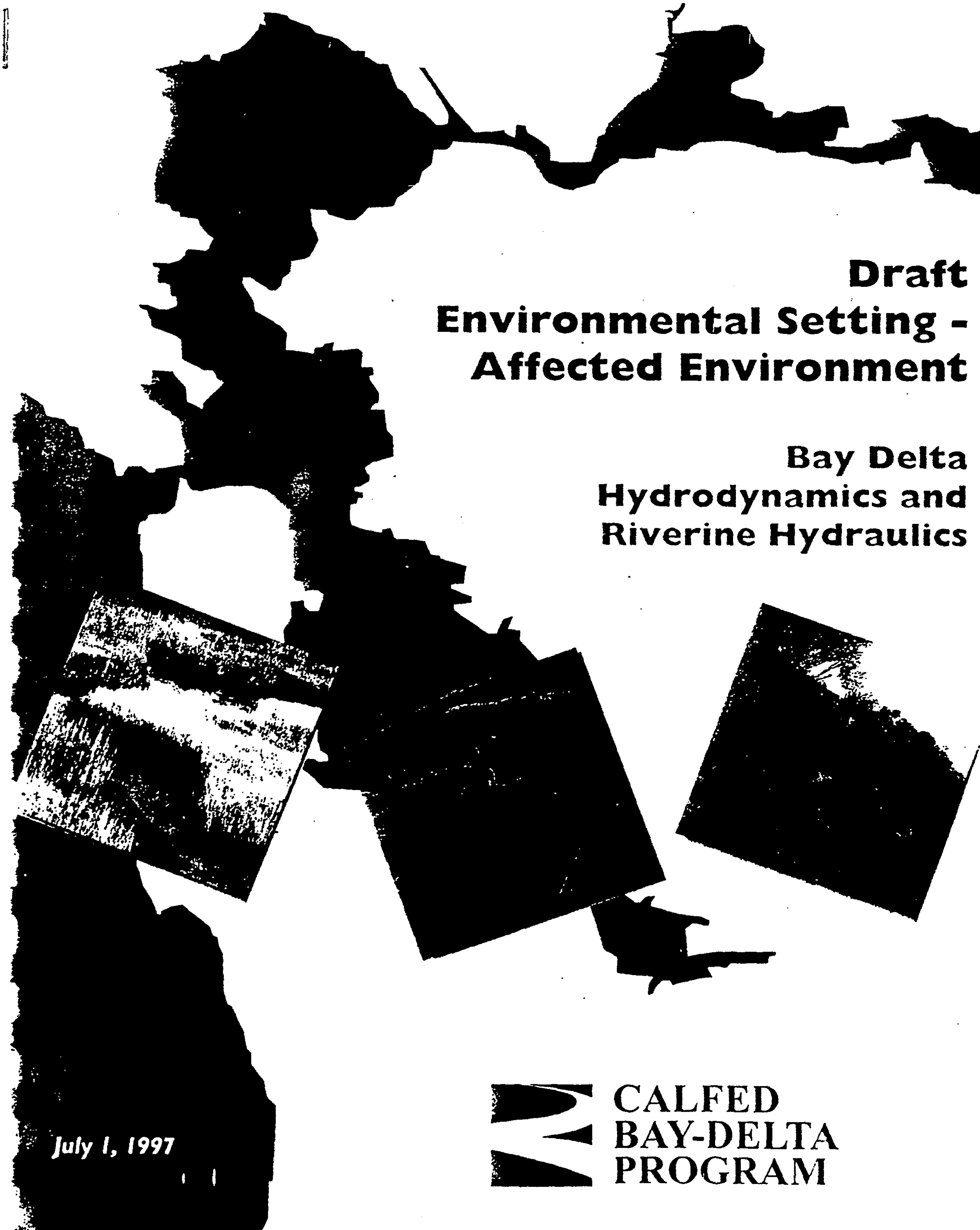
– Comments in pencil by CHRIS ENRIGHT



Draft Environmental Setting - Affected Environment

Bay Delta Hydrodynamics and Riverine Hydraulics

July 1, 1997

CALFED BAY-DELTA PROGRAM

H—000259

CALFED Bay-Delta Program
Environmental Setting - Affected Environment
Bay-Delta Hydrodynamics and Riverine Hydraulics

I. SUMMARY

Existing conditions for the CALFED study area are discussed with a focus on those elements of the system that govern the hydraulic and hydrodynamic conditions. The study area includes the Sacramento-San Joaquin Delta Estuary (the Delta), a portion of San Francisco Bay, and those areas of the Sacramento and San Joaquin Rivers that could potentially be affected by the CALFED program. Hydrodynamic conditions addressed in this report include channel discharge, flow velocity, flow depth, and top width of channels at various points throughout the study area. Representative study locations were selected throughout the Delta and river systems. These locations serve as a focal point for identifying potential program-induced changes to hydrodynamic conditions that are discussed in the environmental consequences report. Study locations include 16 channel segments within the Delta, 9 sections along the Sacramento River and its tributaries, and 3 locations along the San Joaquin River. In addition, this report includes a discussion of salinity within the Delta, particle tracking throughout the Delta, and "X2," which is the location of a regulated salinity contour expressed as distance from the Golden Gate bridge

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II. INTRODUCTION

Delta hydrodynamic conditions influence the movement of water in Delta channels, such as tidal forces and inflows, and the affect the movement of water in Delta channels, such as changes in channel flows and stages and changes in outflow. Delta hydrodynamics depend primarily on the physical arrangement of Delta channels, inflows, diversions, and exports from the Delta and tides. Delta hydrodynamics govern channel flows and Delta outflow dynamics. Channel flows influence water quality, for example, its salinity and dissolved organic carbon, and influence the movement of fish and entrainment of vulnerable organisms (e.g., larval fish and the organisms on which they feed). Delta outflow dynamics have important effects on salinity intrusion and estuarine habitat and conditions.

The discussion of river hydraulics addresses the movement of water within the principal stream channels of the Sacramento and San Joaquin River regions influenced by operation of the California Water Project (CVP) and the State Water Project (SWP). The focus of the discussion is on discharge and its relation to stream velocity, hydraulic geometry (width and depth of the stream), and sediment carrying capacity. Each of these variables has in common a dependence on discharge; that is, if other factors remain the same, a change in discharge will result in a change in the velocity, width, depth, and sediment loading. Temperature and salinity, two additional parameters that relate to river hydrodynamics, also are discussed. Changes in these water quality parameters depend not only on changes in magnitude of discharge but on differences in the quality of discharges from different sources.

III. SOURCES OF INFORMATION

Sources of information for the historical perspective on the San Francisco Bay-Delta include the California Water Plan Update, Bulletin 160-93 (DWR 1994) and the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (SWRCB 1995).

Current resources for the flows, velocities, stages, mass fate, central Delta outflow, and salinity in the Delta region are estimated based on hydrodynamic modeling of the Delta region using the Delta simulation computer model (DWRDSM1). Specific information about the modeling effort is contained in [reference to be provided]. Table 3.1-1 shows key locations in the Delta and their surface area, volume and mean depth, and conveyance used in the hydrodynamic ~~modeling effort.~~ Representative peak tidal discharges are also shown for reference

I think this should be peak tidal discharge! In any case, this variable is not "used", rather, it is calculated...

The primary sources of historical information on rivers in the Sacramento and San Joaquin River regions are water resources data reports published by the US Geological Survey (USGS 1994a. 1994b), and the California Water Plan Update (DWR 1994). Historical daily stream flow records for selected USGS stream gauging stations were obtained from the U.S. Geological Survey's "California Surface-Water Data Retrieval" page on the internet at http://h2o.usgs.gov/nwis-w/CA/.

The most recent resources for river flows were estimated based on computer modeling by the Department of Water Resources using the ~~fixed node~~ statewide water operation planning model DWRSIM. Model output reflecting ~~the most recent conditions~~ a 1995 level of statewide water demands was obtained from study 1995C06F-SWRCB-469, which was completed by the Department of Water Resources (DWR) for the State Water Resources Control Board (SWRCB). The data used in this report were obtained from the DWR's internet site at http://wwwhydro.water.ca.gov/swrcb.html. Study 1995C06F-SWRCB-469, as well as other studies performed by DWR for the SWRCB, are described in the SWRCB's September 12, 1996, report "Bay/Delta Draft EIR Alternatives Under Consideration." Additional information concerning the assumptions used in the model were obtained from the internet web site referenced above. Detailed information describing the DWRSIM model is contained in [reference to be provided].

Equations relating average stream velocity, average stream width and stream depth, and sediment loading to discharge were developed using data for selected stations from 1967 to the present. obtained from the USGS Water Resources Division (Shiffer. personal communication. 1997).

IV. ENVIRONMENTAL SETTING

4.1 Study Area

The study area for this report includes the Sacramento River and San Joaquin River hydrologic regions and San Francisco Bay. The lowermost portion of the Sacramento River and San Joaquin River regions is the Sacramento-San Joaquin Delta (Figure 4.1-1). The San Francisco Bay (Figure 4.1-2), which includes Suisun, San Pablo Central, and South bays, extends about 85 miles from the east end of Chipps Island (in Suisan Bay near the city of Antioch) westward and southward to the mouth of Coyote Creek (tributary to South Bay near the City of San Jose). The Golden Gate connects San Francisco Bay to the Pacific Ocean. The river study area and the locations of points

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hydrodynamics and water quality

Table 3.1-1. Delta channel geometry used in modeling.

Looks like peak tidal flow, not conveyance. Conveyance at MSL is a uniform flow concept. We are modeling close dynamics

Location	Channel Number	Surface Area of Channel Segment (acres)	Volume of Channel Segment (acre-ft)	Depth Below MSL* (ft)	Conveyance at MSL (cfs)
San Joaquin River at Fourteen Mile Slough	22	77.4	2,406	31.1	7,109,000
San Joaquin River at Antioch	51	876.1	21,989	25.1	22,251,000
Old River at Mossdale	54	12.6	102	8.1	206,000
Old River at Fabian Tract	76	28.0	143	5.1	143,000
Old River at Woodward Island	95	56.7	912	16.1	4,233,000
Old River at Franks Tract	121	57.9	585	10.1	873,000
Middle River at Woodward Island	143	30.8	527	17.1	2,975,000
Grant Line Canal	209	21.8	285	13.1	750,000
Victoria Canal	228	34.4	347	10.1	870,000
Delta Cross Channel	365	29.2	470	16.1	1,666,000
Georgiana Slough	366	24.7	348	14.1	586,000
Diversion to Sutter/Steamboat Sloughs	379	10.8	196	18.1	673,000
Miner Slough	388	54.1	762	14.1	761,000
Sacramento River at Rio Vista	430	758.2	19,030	25.1	35,734,000
Mokelumne River, North Fork	362	49.4	993	20.1	1,809,000
Mokelumne River, South Fork	343	51.5	881	17.1	1,808,000

* MSL = Mean Sea Level relative to the National Geodetic Vertical Datum (NGVD) at The Golden Gate

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used in the evaluation of river hydraulics are shown on Figure 4.1-3.

Very little of the water that falls as rain or snow within the region flows unregulated out of the Sacramento River and San Joaquin River regions. Instead, this water is intensely managed to extract from it the maximum benefit. The water is managed through a system of storage facilities and conveyances that enable water managers to deliver water at the time and places where it provides the greatest benefits. In the past, these benefits, or beneficial uses, have been broadly classified as municipal and industrial, agricultural, and fish and wildlife. As management capabilities increase and the effects of management decisions on various systems are increasingly understood, beneficial uses have been defined in greater detail. The State Water Resources Control Board lists 17 specific beneficial uses of water in the Bay-Delta Estuary, each of which is protected. Since stream channels are used as water conveyances, the rules that govern the timing and magnitude of storage and release of water resources determine to a great extent the timing and magnitude of in-stream flows. The principal regulations affecting river and delta flows are discussed in Section 4.2.

4.2 Regulatory Context

The quantity, quality, and timing of flows in river and Delta channels, particularly during below normal runoff years, increasingly depends on the complex body of laws, regulations, plans, and policies that have evolved to set priorities for allocating the resource among its beneficial users. The following section describes the regulatory context as it pertains to channel flows.

Central Valley Project Improvement Act (CVPIA) of 1992. The CVPIA covers the following primary areas:

- Limiting on new and renewed CVP contracts;
- Conserving water and other water management actions;
- Transferring water;
- Establishing fish and wildlife restoration actions; and
- Establishing an environmental restoration fund.

Many of the measures in the CVPIA directly affect the flows in rivers and the Delta. Specifically, the CVPIA requires the following prints ?

- At least an 8,000 cubic foot per second (cfs) pulse flow from Keswick Dam for a five-day period in late April to assist downstream migration of juvenile fall-run chinook salmon and to provide the pulse flow needed in the Delta for Delta smelt and striped bass.
- At least 4,000 cfs releases from Keswick Dam to the Sacramento River from October through March and at least 1,750 cfs releases from Nimbus Dam to the American River from October through February. These releases eliminate flow fluctuations for the spawning, incubation, and rearing of fall-run and late fall-run Chinook salmon and steelhead trout.
- The Delta Cross Channel gates must be closed during May to reduce entrainment of downstream migrating fall-run Chinook salmon, striped bass eggs and larvae, and other Delta species.
- Two pulse flows from New Melones Reservoir of at least 1,500 cfs from April

of Water Right Decision 1485 in 1978. Decision 1485 set forth conditions, including water quality standards, export limitations, and minimum flow rates, for SWP and CVP operations in the Delta and superseded all previous water rights decisions for these operations. Decision 1485 established flow and water quality standards to protect three beneficial uses— municipal and industrial water supply, agriculture, and fish and wildlife.

In formulating Decision 1485, the SWRCB asserted that Delta water quality should be at least as good as it would have been if the SWP and CVP had not been implemented. The standards included different levels of protection to reflect variations in hydrologic conditions during different types of water years. Decision 1485 also included water quality standards for Suisun Marsh.

Decision 1485 was overturned in 1984, but it remained in effect pending appeals was reinstated in 1986 by the Racanelli Decision.

Later in 1986, DWR and the U.S. Bureau of Reclamation (USBR) signed the Coordinated Operation Agreement (COA), obligating the CVP and the SWP to coordinate their operations to meet Decision 1485 standards. The COA helps ensure that the CVP and the SWP will be operated more efficiently during periods of drought than if they were operated independently, and it ensures that each project receives an equitable share of the Central Valley's available water.

Other laws and regulations may indirectly affect Delta hydrodynamics and river hydraulics. These include laws and regulations on the following:

- Water use efficiency;
- Water transfers;
- Releases of water for fish;
- Fish protection;
- Endangered species; and
- Suisun Marsh.

4.3 Other Information

The Department of Water Resources has developed computer models to simulate operation of the CVP-SWP network of storage and conveyance facilities. DWRSIM is one of the primary tools used by the Department of Water Resources to plan the operation of the reservoirs and conveyances and to allocate water within the SWP and CVP. ~~but a~~ A detailed description of ~~the models~~ DWRSIM is beyond the scope of this report, but a detailed description of ~~DWRSIM~~ the model is presented in [**reference to be provided**].

The output from DWRSIM includes calculated monthly flow volumes representing the amount of water in thousands of acre-feet (TAF) that passes a control point defined in the model. These volumes can be readily converted to an average monthly flow rate (i.e. discharge), expressed in cfs. With a few exceptions, the control points generally represent locations within the storage and conveyance system. Typically, the control points are where diversions, storage, downstream flows, regulatory required flows, or tributary inflows need to be adjusted or evaluated. DWRSIM also contains a module to calculate the X2 location in the Delta Estuary.

Section Title

Existing Condition Simulation with DWRSIM

re-work this sentence

~~One of the simulations performed by the Department of Water Resources models existing conditions.~~ The model represents the storage and conveyance facilities as they existed in 1994. The simulation of existing conditions reflects how available water from October 1921 through September 1994 would have been allocated. (This same set of hydrologic inputs representing water years 1922 through 1994 is used in simulations of alternative configurations to study the potential effects on outflows for a reasonably wide range of inflows). The 1994 allocation rules were used in the existing conditions simulations. The results of these simulations are used to describe existing hydraulic conditions in the Sacramento River and San Joaquin River regions in the second part of Sections 4.6 and 4.7.

Does "allocation rules" refer to standards and operations agreements? Could be more specific...

Section Title

DELTA HYDRODYNAMICS VS. RIVER HYDRAULICS

Before it discharges to the San Francisco Bay, stream flow from the Sacramento River and San Joaquin River regions passes through the Sacramento-San Joaquin Delta. Channel hydraulic processes in the region upstream of the Sacramento-San Joaquin Delta are dominated by flows toward the Delta. Tidal effects are generally small enough upstream of the Delta to be ignored. However, in the Delta, tidal flows into and out of San Francisco Bay strongly influence the magnitude and direction of flow in Delta channels and cannot be ignored. Analysis of the combined effects of tidal flows and nontidal flows in the Delta and San Francisco Bay requires different analytical tools from those used to analyze the flows upstream of the Delta. For this reason, Delta and Bay hydrodynamics are discussed separately from river hydraulics in this report.

Section Title

DELTA HYDRODYNAMICS AND WATER QUALITY MODELING USING DWRDSM1

The Department of Water Resources' DWRDSM1 model is one of the primary tools used to ~~manage~~ plan facilities and operations the Sacramento-San Joaquin Delta. A detailed description of the model is beyond the scope of this report, but a description of the model is presented in [reference to be provided].

The modeling of the Delta using DWRDSM1 for the CALFED Programmatic EIR/EIS includes hydrodynamic modeling (i.e., flows, velocities, and stages), mass tracking studies, and salinity modeling. The hydrodynamic modeling was performed using 16 years of monthly average hydrologic data (October 1975 to September 1991) FROM DWRSIM STUDY 1995C06F-S. Three months were selected to represent various flow conditions in the Delta: March 1983, representing high inflow conditions; October 1989, representing low inflow/high pumping conditions; and July 1991, representing low inflow/low pumping conditions. Input stream flows were determined using DWRSIM with projected 2020 demands. DWRDSM1 output included monthly average, minimum, and maximum tidal flows, ~~and~~ velocities, and stages for each channel in the modeling network~~, and stages at each node in the modeling network~~. A subset of the channels ~~and nodes~~ was analyzed in this report.

The mass tracking studies were performed for selected locations within the Delta. Mass was continuously ~~injected~~ released at a particular location and tracked to determine its eventual fate in the Delta. Injection locations ~~consisted of~~ included the Sacramento River at Freeport, the San Joaquin River at Vernalis, Terminous, San Andreas Landing, Prisoners Point, the Sacramento River at Rio Vista, and the San Joaquin River at Jersey Point. ~~Endpoints for~~ The fate of injected mass ~~are as follows:~~ was monitored at Contra Costa Canal, export locations, trapped on Delta islands, remaining in the Delta channels and waterways, or flowing out of the Delta past Chipps Island. Four months were also selected for analysis based on fish and wildlife concerns: February 1979, representing high inflow/high pumping conditions; April 1991, representing

a sentence here motivating use of mass would be helpful. Also, exp that this is essentially "tracer", the transport fate of existed in 1994. The simulation of existing conditions reflects how available water from October 1921 through September 1994 would have been allocated. (This same set of hydrologic inputs representing water years 1922 through 1994 is used in simulations of alternative configurations to study the potential effects on outflows for a reasonably wide range of inflows). The 1994 allocation rules were used in the existing conditions simulations. The results of these simulations are used to describe existing hydraulic conditions in the Sacramento River and San Joaquin River regions in the second part of Sections 4.6 and 4.7.

"allocation rules" refer standards operations agreements? would be more specific...

DELTA HYDRODYNAMICS VS. RIVER HYDRAULICS

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The mass tracking studies were performed for selected locations within the Delta. Mass was continuously released ~~injected~~ at a particular location and tracked to determine its eventual fate in the Delta. Injection locations included ~~consisted of~~ the Sacramento River at Freeport, the San Joaquin River at Vernalis, Terminous, San Andreas Landing, Prisoners Point, the Sacramento River at Rio Vista, and the San Joaquin River at Jersey Point. The fate of ~~Endpoints for~~ injected mass was monitored at ~~are as follows:~~ Contra Costa Canal, export locations, trapped on Delta islands, remaining in the Delta channels and waterways, or flowing out of the Delta past Chipps Island. Four months were also selected for analysis based on fish and wildlife concerns: February 1979, representing high inflow/high pumping conditions; April 1991, representing

a sentence right here motivating use of mass track would be helpful. Also, explain that the mass is essentially "tracer," showing the transport fate of water parcels.

medium inflow/low pumping conditions: October 1989, representing low inflow/high pumping conditions: and July 1991, representing low inflow/low pumping conditions.

Salinity modeling was also performed for key locations within the Delta. ~~The entire 16-year period was modeled~~. Four locations were selected to represent existing conditions: Emmaton, Jersey Point, Old River at Rock Slough, and Clifton Court Forebay.

monthly minimum, maximum and average tidal day salinity was simulated for the 16-year period.

4.4 Delta Region

4.4.1 Historical Perspective

Sources of information for the historical perspective on the San Francisco Bay-Delta include the California Water Plan Update, Bulletin 160-93 (DWR 1994) and the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (SWRCB 1995).

The Sacramento-San Joaquin Delta has been the focus for a variety of water-related issues, generating more investigations than any other waterway system in California in the past few decades. Two-thirds of the state's population and millions of acres of agricultural land receive part or all of their supplies. The Delta provides habitat for many species of fish, birds, mammals, and plants while supporting extensive farming and recreational activities. The following different interest groups have a vital stake in the Delta: farmers, fish and wildlife groups, environmentalists, boaters, people involved with shipping and navigation, and the people and industries that receive water from the Delta and the state's two largest export systems, the SWP and CVP.

During the mid-1800s, the Delta, an area of nearly 750,000 acres, was mostly a tidal marsh, part of an interconnected estuary system that included the Suisun Marsh and San Francisco Bay. The Delta was a great inland lake during the flood season until reclaimed by levees; when the flood waters receded, the network of sloughs and channels reappeared throughout the marsh. Runoff to the Delta comes from over 40 percent of the state's land area, including flows from the Sacramento, San Joaquin, Mokelumne, Cosumnes, and Calaveras rivers and their tributaries.

The first surveys of the Delta channels were in 1841 and again in 1849 by Lt. Commander Cadwalader Ringgold of the U.S. Navy. Due to these surveys, trade between the Delta and upstream communities and the San Francisco Bay Area increased. Delta and northern California communities, already experiencing a population boom because of the Gold Rush, expanded even more as travel to the area became easier and less expensive.

In late 1850, when the Swamp Land Act conveyed ownership of all swamp and overflow land, including Delta marshes, from the federal government to the state government, the development of today's Delta began. The California legislature created the Board of Swamp and Overflowed Land in 1861 to manage reclamation projects. The board's authority was transferred to county boards of supervisors in 1866.

Developers first thought Delta lands would be protected from tides and river overflow by levees about four feet high and 12 feet wide at the bottom. In the 1870s, small-

4.4.2 Current Resource Conditions

4.4.2.1 Flows, Velocities, and Stages

Average flows, velocities, and stages for high flow, low inflow/high pumping, and low inflow/low pumping conditions are presented in Table 4.4-1 for a number of locations within the Delta. ~~These flows are based on modeling of the Delta with existing Delta geometry and predicted 2020 demands.~~ This demand is ~~which are~~ higher than current demands; thus, pumping rates and, therefore, flows toward the pumping plants, may be less for existing conditions than those presented in the table.

The input hydrology is from DWRSIM study which provides monthly average river inflows and project exports under predicted 2020 demands.

During periods of high flow, the Delta Cross Channel is closed for delta flood protection. ~~not needed to convey water to the pumps in the south Delta.~~ Higher flows are observed in locations along the Sacramento River and in the North Delta, while flows in the south Delta are generally lower. Average flow rates range from 0 to 185,000 cfs for high flow conditions, 30 to 6,200 cfs in low flow/high pumping conditions and 30 to 2,900 cfs for low flow/low pumping conditions.

Velocities in the Delta are generally well below the nominal scour velocity of approximately three fps except at a few locations in high flow conditions—Old River at Mossdale, Grant Line Canal, the Diversion to Sutter and Steamboat sloughs, and the Sacramento River at Rio Vista.

Since DWRDSM only provides cross-section average velocity, the result should be considered as indices for comparative purposes

Maps of the average tidal flows, velocities, and stages throughout the Delta based on modeling are shown in Figures 4.4-1 through 4.4-3 for the high flow, low inflow/high pumping and low inflow/low pumping conditions, respectively. For high flow conditions, approximately 40 percent of the inflow from the Sacramento River at Hood is diverted to Steamboat Slough and Sutter Slough, and 15 percent travels down Georgiana Slough. The remainder continues down the Sacramento River toward the Bay. In the South Delta, about 60 percent of the San Joaquin River inflow at Vernalis, is diverted to Old River near Mossdale and 40 percent remains in the San Joaquin River channel and flows past Stockton. Of the flow diverted to Old River, approximately five percent travels down Middle River toward the Bay, 75 percent is carried by the Grant Line Canal, and 20 percent is carried by Old River toward the pumping plants. Water in Victoria Canal, Old River north of Victoria Island, and Middle River travels north toward the Bay. The ratio of flow in Old River to flow in Middle River is about 1.5. Water from the central Delta flows out through the San Joaquin River and through Franks Tract and connecting channels (False River and Dutch Slough). Central Delta water includes inflows from the San Joaquin River and east side streams, as well as Sacramento River flow diverted through Georgiana Slough. False River carries ~~a fraction of~~ about 35 percent of the central-Delta outflow, and Dutch Slough carries about five percent. About 60 percent of the total central Delta outflow remains in the main channel of the San Joaquin River. X

For low inflow/high pumping conditions, approximately 20 percent of the inflow from the Sacramento River at Hood is diverted to Steamboat Slough and Sutter Slough, 30 percent is diverted to the Delta Cross Channel, and 20 percent travels down Georgiana Slough. The remainder continues down the Sacramento River toward the Bay. In the South Delta, the San Joaquin River experiences reverse flows. Of the flow in Old River at Mossdale, approximately 85 percent is carried by the Grant Line Canal and 10 percent is carried by Old River toward the pumping plants. Water in Victoria Canal, Old

River north of Victoria Island, and Middle River travels south toward the Delta export locations at the Banks and Tracy Pumping Plants. The ratio of flow in Old River to flow in Middle River is about 1.5. Much of the water in the central Delta flows south toward the pumping plants. Central Delta water enters Old and Middle River channels at their mouths and flows through Turner, Empire, and Columbia Cuts, which connect the upper San Joaquin River with Middle River. Central Delta water includes inflows from the San Joaquin River and east side streams, as well as Sacramento River flow diverted through the Delta Cross Channel and Georgiana Slough. False River, Dutch Slough, and the San Joaquin River carry water east into the Delta.

For low inflow/low pumping conditions, approximately 20 percent of the inflow from the Sacramento River at Hood is diverted to Steamboat Slough and Sutter Slough, 35 percent is diverted to the Delta Cross Channel, and 25 percent travels down Georgiana Slough. The remainder continues down the Sacramento River toward the Bay. In the South Delta, about 80 percent of the San Joaquin River inflow at Vernalis, is diverted to Old River near Mossdale and 20 percent remains in the San Joaquin River channel and flows past Stockton. Of the flow diverted to Old River, approximately five percent travels down Middle River toward the Bay, while 60 percent is carried by the Grant Line Canal and five percent is carried by Old River toward the pumping plants. Water in Victoria Canal, Old River north of Victoria Island, and Middle River travels south toward the Delta export locations at the Banks and Tracy Pumping Plants. Old River and Middle River carry nearly equal amounts of this flow. Much of the water in the central Delta flows west toward the Bay. Central Delta water enters Old and Middle River channels at their mouths and flows through Turner, Empire, and Columbia Cuts, which connect the upper San Joaquin River with Middle River. Central Delta water includes inflows from the San Joaquin River and east side streams, as well as Sacramento River flow diverted through the Delta Cross Channel and Georgiana Slough. False River, Dutch Slough, and the San Joaquin River carry water west toward the Bay.

Average velocities in the Delta for both low inflow/high pumping conditions and low inflow/low pumping conditions are below the nominal scour velocity of approximately three fps at all locations within the Delta. Average velocities in the Delta for high flow conditions are generally below the scour velocity ~~of three fps~~, except on the outskirts. The Sacramento River at Hood, diversion to Steamboat/Sutter Sloughs, Steamboat Slough, San Joaquin River at Upper Roberts Island, Old River at Mossdale, and Grant Line Canal all have average velocities higher than 3 fps. However, Grant Line Canal has average velocity of less than three fps in less than one percent of the months modeled, the San Joaquin River at Upper Roberts Island in less than six percent of the months modeled, the Diversion to Steamboat and Sutter Sloughs, Steamboat Slough, and the Sacramento River at Hood in less than 12 percent of the months modeled, and Old River at Mossdale in less than 18 percent of the months modeled.

Comment: I would reduce the emphasis given to 3 fps average velocity for scouring. Tidal velocities are higher and really control scouring, not average velocities. Also the modeled results is a cross-section average, which is not indicative of near-bed velocities. Therefore, all velocity info should be couched as "index" info for comparative purposes. 3 fps is really only an index of scour concern.

4.4.2.2 ~~Mass Fate~~ TRANSPORT AND FATE OF TRACER MASS

The fate of mass ~~injected~~ released into the Delta at various locations after 30 and 60 days is shown in Table 4.4-2 for a number of flow conditions. The flow conditions are low flow/high pumping, low inflow/low pumping, high inflow/high pumping, and medium inflow/low pumping. These flow conditions were chosen based on fisheries and wildlife issues.

Most of the mass ~~injected~~ released at the San Joaquin River near Vernalis ends up at the export locations for all flow conditions except low inflow/low pumping, where more is on Delta islands due to the decreased demand at the pumps. None of the mass injected at Vernalis reaches the Contra Costa Canal or flows past Chipps Island except at high inflow/high pumping conditions, where a small amount flows past Chipps Island.

For the mass injected at Terminous for low inflow/high pumping and medium inflow/low pumping conditions, most of the mass eventually goes to the exports, very little flows past Chipps Island and flows to the Contra Costa Canal, and some is trapped on Delta islands. For low inflow/low pumping conditions, less mass flows to the exports, and most of the mass is eventually trapped on Delta islands. For high inflow/high pumping conditions, most of the mass flows past Chipps Island.

For the mass injected into the Sacramento River at Freeport, for low inflow/high pumping conditions, most of the mass flows past Chipps Island. For low inflow/low pumping conditions, more mass is trapped in Delta islands and Delta channels and waterways after 60 days. For both high and medium inflow conditions, most of the mass flows past Chipps Island, though the mass takes longer to do so under medium flow conditions.

For the mass injected in the Sacramento River at Rio Vista and in the San Joaquin River at Jersey Point, for all flow conditions, most of the mass flows past Chipps Island. The mass is quickest to reach Chipps Island in the high inflow case and the slowest under the low inflow/low pumping conditions. Also, under low inflow conditions, more mass is trapped on Delta islands.

For mass injected in the San Joaquin River at San Andreas Landing, under high and medium inflow conditions, most of the mass eventually flows past Chipps Island. For the medium inflow case, the mass takes longer to reach Chipps Island, more reaches the export locations, and more is trapped on Delta islands. For low inflow/high pumping conditions, nearly equal amounts of mass reach the export locations as flow past Chipps Island. For low inflow/low pumping conditions, the mass is fairly evenly distributed for reaching the exports, being trapped on Delta islands, flowing past Chipps Island, and remaining in Delta channels after 60 days.

For mass injected into the San Joaquin River at Prisoners Point, for low and medium inflow conditions, most of the mass reaches the export locations and more is trapped on Delta islands for low pumping conditions than for high pumping conditions. For high flow conditions, most of the mass flows past Chipps Island, with a small amount reaching the export locations.

This analysis of the fate of mass ~~injected~~ released into Delta waterways at various locations is based on DWRDSM1 modeling using predicted 2020 demands and an increased pumping capacity at the export locations. Both of these components would increase the pumping that occurs and, therefore, would increase the mass traveling to the export locations. Therefore, under existing Delta conditions, there would likely be less mass reaching the export locations and more flowing past Chipps Island and becoming trapped on Delta islands.

Table 4.4-2. Fate of mass ~~injected~~ released at specific locations for existing conditions.

	Low Inflow/ High Pumping		Low Inflow/ Low Pumping		High Inflow/ High Pumping		Medium Inflow/ Low Pumping	
Vernalis	**30 days**	**60 days**	**30 days**	**60 days**	**30 days**	**60 days**	**30 days**	**60 days**
Chipps Island	0%	0%	0%	0%	4%	8%	0%	0%
Contra Costa Canal	0%	0%	0%	0%	1%	1%	0%	0%
Exports	67%	72%	31%	32%	88%	91%	77%	87%
Islands	18%	20%	61%	64%	0%	0%	10%	11%
In Delta	15%	8%	6%	4%	7%	0%	13%	2%
Terminous	**30 days**	**60 days**	**30 days**	**60 days**	**30 days**	**60 days**	**30 days**	**60 days**
Chipps Island	0%	4%	0%	1%	56%	78%	1%	8%
Contra Costa Canal	1%	3%	1%	3%	1%	1%	0%	0%
Exports	19%	56%	10%	29%	14%	20%	25%	64%
Islands	11%	15%	39%	54%	0%	0%	8%	12%
In Delta	69%	20%	49%	12%	29%	1%	66%	16%
Freeport	**30 days**	**60 days**	**30 days**	**60 days**	**30 days**	**60 days**	**30 days**	**60 days**
Chipps Island	19%	46%	10%	28%	98%	99%	69%	81%
Contra Costa Canal	1%	2%	1%	3%	0%	0%	0%	0%
Exports	6%	22%	4%	15%	1%	1%	5%	10%
Islands	8%	11%	26%	35%	0%	0%	3%	4%
In Delta	65%	20%	59%	19%	1%	0%	23%	4%
Rio Vista	**30 days**	**60 days**	**30 days**	**60 days**	**30 days**	**60 days**	**30 days**	**60 days**
Chipps Island	50%	79%	35%	62%	100%	100%	87%	94%
Delta Cross Channel	1%	1%	1%	2%	0%	0%	0%	0%
Exports	2%	5%	2%	5%	0%	0%	2%	3%
Islands	2%	3%	8%	11%	0%	0%	1%	2%
In Delta	45%	12%	55%	19%	0%	0%	10%	1%
Jersey Point	**30 days**	**60 days**	**30 days**	**60 days**	**30 days**	**60 days**	**30 days**	**60 days**
Chipps Island	40%	72%	27%	55%	98%	99%	62%	82%
Contra Costa Canal	1%	2%	2%	3%	0%	0%	0%	0%
Exports	7%	9%	6%	9%	1%	1%	8%	10%
Islands	3%	4%	9%	12%	0%	0%	3%	4%
In Delta	49%	13%	56%	20%	1%	0%	27%	4%
San Andreas Landing	**30 days**	**60 days**	**30 days**	**60 days**	**30 days**	**60 days**	**30 days**	**60 days**
Chipps Island	13%	39%	6%	23%	94%	97%	26%	51%
Contra Costa Canal	2%	3%	3%	5%	0%	0%	0%	0%
Exports	15%	33%	12%	28%	3%	3%	18%	34%
Islands	4%	7%	14%	23%	0%	0%	4%	6%
In Delta	66%	18%	65%	21%	3%	0%	53%	9%
Prisoners Point	**30 days**	**60 days**	**30 days**	**60 days**	**30 days**	**60 days**	**30 days**	**60 days**
Chipps Island	2%	10%	1%	6%	74%	87%	6%	16%
Contra Costa Canal	3%	4%	4%	6%	1%	1%	0%	0%
Exports	42%	68%	30%	49%	10%	12%	47%	72%
Islands	5%	8%	21%	31%	0%	0%	4%	6%
In Delta	48%	10%	44%	9%	15%	0%	43%	6%

4.4.2.3 Net Delta Outflow

The Delta is a tidal region with tides causing a ~~five~~- to eight-mile back and forth movement of water in the Delta twice each day. The net movement of fresh water through the Delta can be thought of as being superimposed on the tidal flows. The tidal flows into and out of the Delta ~~are thought to~~ essentially cancel each other out; thus, an equal amount of water flows into the Delta and then flows back out with no net movement of water through the system. Although the fresh water river flows are small in comparison to the tidal flows, they are the source of "net" movement in and through the Delta.

zero

There are however, ebb-flood tide asymmetries due to the branch and loop nature of the delta channel configuration which is very important

Net Delta outflow is thought to be the means that fish use to navigate upstream, that fish eggs and larvae use to move through the Delta, and by which ~~that~~ dissolved substances, such as salt, are flushed through the Delta. SWRCB has used Delta outflow, Sacramento River flow at Rio Vista, and San Joaquin River flow at Vernalis to create Water Quality Objectives in its water quality control plan (1995). The objectives set minimum flow requirements at these points during specific times of the year.

Net Delta outflow represents the net flow ~~on the~~ below the San Joaquin River, confluence Sacramento River near Chipps Island moving out of the Delta. Net Delta outflow cannot easily be measured because of the large overshadowing effect of the tidal flows.

X

No, by definition, the average tidal flow = 0

The average tidal flow at Chipps Island is about 170,000 cfs. The peak tidal ebb and flood flows are about 320,000 cfs and 310,000 cfs, respectively, the difference accounting for net delta outflow. In comparison, average winter net Delta outflow is about 32,000 cfs, with summer time flows averaging 6,000 cfs (DWR 1993). Net Delta outflow is the difference between the tidal inflows and tidal plus river outflows (exports and channel depletions).

Table 4.4-3 shows the distribution of monthly averaged net Delta outflow for existing conditions based on DWRSIM modeling. From 1923 through 1994, average annual Delta outflow was 20,700 cfs and ranged from 5,500 cfs to 94,300 cfs. Monthly average flows are frequently as low as 3,000 cfs in the summer and as high as 148,000 cfs in winter (five and 95 percentiles, respectively).

February typically has the greatest variation of net Delta outflow, ranging from 11,000 cfs to 148,000 cfs for the fifth and 95th percentiles, respectively, in addition to the largest median flow of 31,000 cfs. August has the least variation of net Delta outflow, ranging from 3,000 cfs to 5,000 cfs for the fifth and 95th percentiles, respectively. The low flows are commonly a function of the minimum Delta outflow requirements.

4.4.2.4 Central Delta Outflow

rework this sentence (unclear)

Central Delta outflow is the existence of reverse flows in the lower San Joaquin River and in the southern Delta area. ~~The large~~ export pumping plants of the CVP and SWP can cause water in the southern channels to move upstream toward Clifton Court. The two terms used to describe and compute reverse flow are QWEST and Central Delta Outflow. QWEST represents the flow in the lower San Joaquin River at Jersey Point; Central Delta outflow represents the net flow in the San Joaquin River upstream of Three Mile Slough plus False River and Dutch Slough. Only central Delta outflow is discussed here.

Central Delta outflow represents the net flow in the San Joaquin River upstream of Three Mile Slough plus False River and Dutch Slough. Central Delta outflows are either downstream in a typical flow pattern or drawn upstream toward the export pumping plants in the southern Delta. Reverse flows are a result of high export pumping in the southern Delta compared to the low inflows of the San Joaquin River and southern channel capacities. The difference between the exports and the southern Delta inflows are made up from the Sacramento River and east side streams, drawing water across the Delta from the north and west to the south.

Upstream flows appear to occur in every year between 1976 and 1991, except in 1983, which experienced the highest Delta flows on record (66,000 TAF). During the 1976-1977 drought and the 1987-1991 drought, flows were almost always upstream. Frequency analysis of central delta outflows indicates that approximately 60 percent of the monthly averaged flows are in the upstream direction.

Table 4.4-4 shows the distribution of monthly averaged central delta outflow for existing conditions based on DWRDSM1 modeling. These flows are based on modeling of the Delta with existing Delta geometry and predicted 2020 demands, which are higher than current demands; thus, pumping rates may be less for existing conditions, and magnitudes of central delta outflow may be less extreme than those shown in the table.

Central Delta outflows show typical winter and spring characteristic flows and summer and fall characteristic flows. Median flows in mid-winter through spring are downstream, while median flows in summer through fall are upstream. Approximately 70 percent of the central delta outflows in the late winter through spring are downstream. Flows in April are always downstream. Approximately 70 percent of the central delta outflows in the summer and fall are in the upstream direction.

4.4.2.5 X2 Position

The X2 position represents the approximate location of the beginning of the entrapment zone, or mixing zone, of seawater from the bay and fresh water from the streams. The X2 position is the theoretical location of the two parts per thousand salinity isohaline. The location of X2 varies in relationship to net Delta outflow and the tidal cycle. X2 is measured in kilometers from the Golden Gate Bridge upstream to the Sacramento River. During high Delta outflows, X2 can be located near Suisun Bay; with low Delta outflows, X2 can be located in the western Delta, sometimes as far upstream as Jersey Point. The tide can move X2 from three to 10 kilometers each day (California State Lands Commission 1991). As with other standards, X2 is part of the DWRSIM operation decision structure. A comparison of percentiles is presented to help evaluate impacts in Delta outflow, changes in the entrapment zone, and potential impacts on the Bay.

It might be explained the X2 is appar[ently] correlated wi[th] the abundance [of] several aquatic species than provision of habitat...

Table 4.4-5 shows the distribution of computed X2 positions obtained from DWRSIM simulation for existing conditions. X2 ranges from 42 kilometers in March 1983 to about 90 kilometers in August, September, and October (years 1929, 1931, 1933).

4.4.2.6 Salinity

A key factor in the health of the Delta is the relationship between salinity and the ecology of the estuary. During the dry season, salt water from the Pacific Ocean moves landward within the Bay to the Delta; during the wet winter season, salt water moves seaward, driven by the increased discharge of fresh water. The principal sources of fresh water to the Delta are the Sacramento River and San Joaquin River. Salinity also varies from year about 85 miles from the east end of Chipps Island (in Suisun Bay near the city of Antioch) westward and southward to the mouth of Coyote Creek (tributary to South Bay near the city of San Jose). The Golden Gate connects San Francisco Bay to the Pacific Ocean.

San Francisco Bay has a surface area of about 400 square miles at mean tide. This is about a 40 percent reduction from its original size due to fill. Most of the Bay's shoreline has a flat slope, which causes a relatively large intertidal zone. The volume of water in the Bay changes by about 21 percent from mean higher-high tide to mean lower-low tide. The overall average depth of the Bay is 20 feet, with the Central Bay averaging 43 feet and the South Bay averaging 15 feet (DWR 1986). San Francisco Bay is surrounded by about 130 square miles of tidal flats and marshes.

Delta outflow is the principal source of fresh water in San Francisco Bay. Delta outflows vary greatly according to month and hydrologic year type. During critically dry periods, such as 1928 and 1934, historical Delta outflows have dropped to zero. Present summer outflows are maintained by upstream reservoir releases.

San Francisco Bay receives freshwater inflow from the following other significant sources: the Napa, Petaluma, and Guadalupe rivers, and Alameda, Coyote, Walnut, and Sonoma creeks. The total average inflow of these tributaries is about 350 thousand acre-feet. Stream flow is highly seasonal, with more than 90 percent of the annual runoff occurring during November through April. Many streams often have very little flow during mid- or late-summer.

Suisun Bay

Below the Delta, the first embayment is Suisun Bay. This bay, which includes Grizzly and Honker bays, is the area where the effects of mixing seaward-flowing fresh water and landward-flowing salt water (driven by tides) are most pronounced. Salt water tends to move landward under river water since it is slightly heavier than fresh water. However, this effect is seen only slightly in the upper Bay and Delta. The complex circulation patterns cause a concentration of small plants, larval fish, and other animals within this zone. This area of concentration is called the entrapment zone, or zone of maximum turbidity, and is a feature of all estuaries that receive significant amounts of fresh water. The location of the entrapment zone in the Suisun Bay and adjacent extensive areas of productive shallow water is considered to be an important ecological feature of the Bay-Delta Estuary complex. This zone moves upstream and downstream in the estuary depending on the amount of fresh water outflows. X2 is used to define the location of the entrapment zone in kilometers from the Golden Gate Bridge. It is thought to be best when located near Suisun Marsh, which occurs during high flows. During low flows, X2 can be as far upstream as Jersey Point.

Adjacent to Suisun Bay is the Suisun Marsh. Suisun Marsh is about 80,000 acres of brackish water containing a significant percentage of the remaining contiguous wetlands in California. This managed marsh along with the other tidal wetlands around the Bay-Delta Estuary, provide valuable habitat for a variety of plants and animals, especially waterfowl. They also contribute significant amounts of nutrients to the estuarine system.

not all near "managed" to diked wetland

Below the Carquinez Strait are the San Pablo and central San Francisco bays. Carquinez Strait isolates these bays from the Suisun Bay and the Delta and allows such oceanic conditions as tides to play a leading role in their salinity and circulation. These embayments can become quite fresh,